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RESEARCH MEMORANDUM

for the

U. S. Air Force

SERVICE REPORT

INVESTIGATION OF EJECTION RELEASES OF AN MB-1 ROCKET FROM A 0.04956-SCALED MODEL OF THE CONVAIR F-106A AIRPLANE AT MACH NUMBER 1.59

COORD. NO. AF-AM-57

[redacted]

By John B. Lee

Langley Aeronautical Laboratory
Langley Field, Va.

CLASSIFICATION CHANGE

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

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INVESTIGATION OF EJECTION RELEASES OF AN MB-1 ROCKET FROM A 0.04956-SCALED MODEL OF THE CONVAIR F-106A AIRPLANE AT MACH NUMBER 1.59

COORD. NO. AF-AM-57

By John B. Lee

SUMMARY

An investigation has been conducted in the 27- by 27-inch preflight jet of the Langley Pilotless Aircraft Research Station at Wallops Island, Va., of the ejection release characteristics of the MB-1 rocket from the missile bay of a 0.04956-scaled model of the Convair F-106A airplane. The MB-1 rocket was ejected with its fin tips retracted, for a simulated altitude of 18,670 feet at a Mach number of 1.59.

Successful ejections were made with the MB-1 rocket at supersonic speeds by applying a proper combination of ejection velocity and nose-down pitching moment to the rocket at release. The pitching moment at release required to keep the MB-1 rocket at a near level attitude after release was influenced by the presence and number of Falcon missiles in the missile bay.

INTRODUCTION

At the request of the U. S. Air Force, an investigation was made to determine the ejection characteristics of an internally carried MB-1 rocket from the missile bay of a model of the Convair F-106A airplane. To carry the rocket in the F-106A, the fin tips are retracted inside the fins with the fin tips telescoping out upon the firing of the rocket. It is required that the rocket be at near level flight upon the firing of the rocket motor

and the extension of the fin tips. Adverse pitching moments of a store due to aerodynamic forces, in the vicinity of the missile bay and fuselage, may endanger the airplane. It was thus necessary to investigate the release characteristics of the rocket and develop an ejection method that would give the desired rocket attitude at the instant of rocket firing. This investigation included a study of the rocket with fins retracted only. An ejector was designed that would impart an initial pitching moment to the rocket at release that would overcome any adverse pitching.

In reference 1, from a comparison of static and dynamic tests, there were strong indications that model tests should include all pertinent details of the full-scale bomb bay. Additional investigations of dynamic models (refs. 2 and 3) also showed this to be true. The missile bay of the F-106A is designed to carry up to four Falcon missiles with the MB-1 rocket. This investigation included these Falcon missiles with their rail launchers. The effects of several missile bay configurations with and without Falcon missiles were investigated.

The models were dynamically scaled by the light-model method as outlined in reference 4. The models simulated an altitude of 18,670 feet at a Mach number of 1.59 with a Reynolds number of approximately 11.3×10^6 per foot. This investigation was made with a 0.04956-scaled model in the preflight jet of the Langley Pilotless Aircraft Research Station at Wallops Island, Va.

SYMBOLS

d diameter, 0.859 in. for rocket missile

l rocket model length, in.

M Mach number

M_o equivalent full-scale applied moment at rocket release, positive nose up, ft-lb

N_f number of Falcon missiles in missile bay

r radius, in.

t time, sec

Δt time interval of stroboscopic photographs, sec

x horizontal distance of rocket model center of gravity with origin at point of release, positive downstream, in.

z vertical distance of rocket model center of gravity with origin at point of release, positive down, in.

$\dot{z}_o$ ejection velocity of rocket model at point of release, ft/sec

α_f angle of attack of airplane fuselage, deg

θ_M rocket model pitch angle in reference to undisturbed free-stream direction, deg

MODELS AND APPARATUS

MB-1 Rocket

A photograph and a sketch of the MB-1 rocket with retracted fin tips are shown in figure 1, and the rocket model ordinates are shown in table I. To store the rocket in the missile bay of the full-scale airplane, with Falcon missiles, the MB-1 fin tips are retracted into their respective fins. For this investigation only models with retracted fins were used.

The MB-1 rocket has a fineness ratio of 6.4 and a center-of-gravity position of 55 percent of the rocket length from the nose. Figure 1(b) shows the position of the ejection pins. The rocket was carried in the missile bay at a negative incidence angle of 2° with the airplane. All tests for this investigation were made at a fuselage angle of attack of 2°.

A model weight of 0.201 pound and an inertia of 0.441 pound-square inch simulated an altitude of 18,670 feet for a full-scale weight of 800 pounds and an inertia of 720,000 pounds-square inches.

Fuselage and Missile Bay

A sketch of the 0.04956-scaled model of the Convair F-106A airplane used for this investigation is shown in figure 2. The model was attached to an extension of the nozzle plate by two struts, one attached to each wing. The nose of the model extended into the nozzle, and the front end of the MB-1 rocket was approximately 3/8 inch downstream of the nozzle exit. The airplane model was at a 2° angle of attack in the test section. Figure 2 shows the model set up with $\alpha_f = 0^{\circ}$.

The missile bay was constructed to carry four Falcon missiles in addition to the MB-1 rocket. The Falcon missiles were removable from the model missile bay as necessary for the tests. For a missile-bay combination of two Falcon missiles, ($N_f = 2$) the two forward Falcon missiles were in place with the two rear Falcon missiles removed.

Ejection Mechanism

An ejector cylinder was located directly above the model on the nozzle-top-plate extension (fig. 2(a)). The ejector rods passed through protective rods that connected to the top of the airplane model. An air-pressure cylinder applied force to a crossbar (fig. 2(a)). The ejector cylinder with the crossbar could be adjusted to apply different forces to the ejector rods to obtain the desired pitching moment of the rocket. The rocket was locked into the ejector rods by pins backed by tension springs. The force of the ejector rods on the ejector pins would overcome the force of the tension springs and the model would be ejected. The ejection stroke length was 0.5 inch.

Preflight Jet

This investigation was made in the 27- by 27-inch preflight jet of the Langley Pilotless Aircraft Research Station at Wallops Island, Va. The test setup is shown in figure 2. A description of the tunnel is given in reference 4.

Photography

Stroboscopic photographs were obtained by using a spinning disk with slits in front of the camera lens (ref. 2). The time interval between frames was approximately 0.002 second.

RESULTS AND DISCUSSION

The purpose of this investigation was to determine the flight characteristics of the MB-1 rocket in the vicinity of the airplane and to determine the type of release necessary to maintain a near level flight attitude. Table II gives the tests and the pertinent data of each test. Figures 3 to 6 present the stroboscopic pictures and plots of the rocket-model oscillations and trajectory. Distances divided by the maximum rocket-model diameter of $d = 0.859$ are shown in the motion plots to nondimensionalize the results.

This investigation was made at $M = 1.59$, and an altitude of 18,670 feet was simulated. The airplane angle of attack was 2° and the rocket incidence angle to the airplane was -2°. Combinations of Falcon missiles in the missile bay included $N_f = 0$, 2, and 4; where $N_f = 2$, the two front Falcon missiles were included. Ejections were made at $\dot{z}_o = 23.0$ to 29.0 feet per second and the pitching moment at release M_o was equivalent to -1,100 to -2,000 foot-pounds, full scale.

Figure 3 shows the effect of changing the pitching moment at release from -2,000 to -1,100 foot-pounds with $\dot{z}_o = 29.0$ and 28.5 feet per second, respectively, with $N_f = 0$. The pitching moment of -2,000 foot-pounds at release, test 1, was excessive and caused the MB-1 rocket to pass through the airstream in a nose-down attitude. With a decrease in pitching moment to -1,100 foot-pounds, test 2, the rocket pitch attitude reached a maximum θ_M of -10° at approximately 5 rocket diameters below the release point (fig. 3(d)). The rocket pitch attitude was 0° at 10 store diameters and stayed within $\theta_M = 4^{\circ}$ thereafter. Therefore, by regulating the pitching moment at release, the desired pitch attitude can be obtained to allow the firing of the missile rocket.

Ejections of the MB-1 rocket at $\dot{z}_o = 28.5$ feet per second and $M_o = -1{,}100$ foot-pounds with different missile-bay combinations of Falcon missiles are shown in figure 4. Test 2 is repeated in figures 4(b), (c), and (d) for comparison purposes. With two Falcon missiles in the missile bay, the rocket pitch attitude remained within -12° for 10 store diameters and then pitched to a larger negative angle (test 3). With four Falcon missiles in the missile bay, test 4, the MB-1 rocket pitched nose up after release and diverged. The rocket pitch angle, however, was less than 10° for 8 rocket diameters below the release point. Test 5, made under identical conditions, checked the results of test 4, indicating the degree of repeatability of the test technique even for divergent conditions. The missile-bay configuration is thus shown to have a large effect on the rocket pitching characteristics; however, the rocket trajectories for all tests remained approximately the same for 10 store diameters.

The greatest change in release conditions appeared between missile-bay combinations of $N_f = 2$, test 3, and $N_f = 4$, test 4, with the rocket changing from a nose-down attitude to a divergent nose-up attitude, respectively. The change between $N_f = 0$ and $N_f = 2$ was small and the releases considered favorable, even for a case of a rocket misfire.

The effect of missile bay combinations with $M_o = -2{,}000$ foot-pounds on the MB-1 trajectory is shown in figure 5. For test 1, $N_f = 0$, and test 6, $N_f = 2$, the rocket had pitched to -30° or more by the time the

missile was 10 store diameters below the release point. In test 4, however, with $N_f = 4$, the MB-1 rocket remained within $\theta_M = -11^\circ$ for 13 rocket diameters below the release point.

It thus appears that $M_o = -1,100$ foot-pounds is sufficient for missile bay configurations of $N_f = 0$ and $N_f = 2$ with high ejection velocities. If the missile rocket fires within 8 store diameters of the release point, $M_o = -1,100$ foot-pounds should also be sufficient for $N_f = 4$. However, an increase of pitching moment of over 80 percent, up to -2,000 foot-pounds, is needed to keep the rocket in an attitude that would not endanger the airplane in case of a rocket misfire. It thus appears that the elimination of the two rear Falcon missiles would simplify the release problems; that is, a smaller range of pitching moment and ejection velocity would be needed to obtain good releases.

The ejection velocity was decreased to 23 feet per second (fig. 6) with $M_o = -1,170$ foot-pounds. For all missile-bay configurations the rocket pitched to a high positive angle. The rocket remained below $\theta_M = 10^\circ$ within 7 store diameters of the release point in all cases. Thus a decrease in ejection velocity without a corresponding increase in nose-down pitching moment may yield unsatisfactory release characteristics.

CONCLUSIONS

An experimental investigation was conducted in a free jet to determine the ejection release characteristics and flight behavior of the MB-1 rocket in the close vicinity of the fuselage of a model of the Convair F-106A airplane. The tests were made at a Mach number of 1.59 for a simulated altitude of 18,670 feet. The Reynolds number was 11.3×10^6 per foot.

Changes in missile-bay configurations by the addition of Falcon missiles caused a large change in the MB-1 release characteristics. Successful ejections were made by applying a proper combination of

ejection velocity and nose-down pitching moment at release to overcome the aerodynamic forces produced in the vicinity of the fuselage and missile bay.

Langley Aeronautical Laboratory,
National Advisory Committee of Aeronautics,
Langley Field, Va., April 15, 1957.

John B. Lee
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Aeronautical Research Engineer

Approved:
Joseph A. Shortal
Joseph A. Shortal
Chief of Pilotless Aircraft Research Division

sam

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1. Faget, Maxime A., and Carlson, Harry W.: Experimental Techniques for Predicting Store Motions During Release or Ejection. NACA RM L55L20b, 1956.

2. Lee, John B., and Carter, Howard S.: An Investigation of Ejection Releases of Submerged and Semisubmerged Dynamically Scaled Stores From a Simulated Bomb Bay of a Fighter-Bomber Airplane at Supersonic Speeds. NACA RM L56I10, 1956.

3. Carter, Howard S., and Lee, John B.: Investigation of the Ejection Release of Several Dynamically Scaled Bluff Internal Stores at Mach Numbers of 0.8, 1.39, and 1.98. NACA RM L56H28, 1956.

4. Sandahl, Carl A., and Faget, Maxime A.: Similitude Relations for Free-Model Wind-Tunnel Studies of Store-Dropping Problems. NACA TN 3907, 1957.

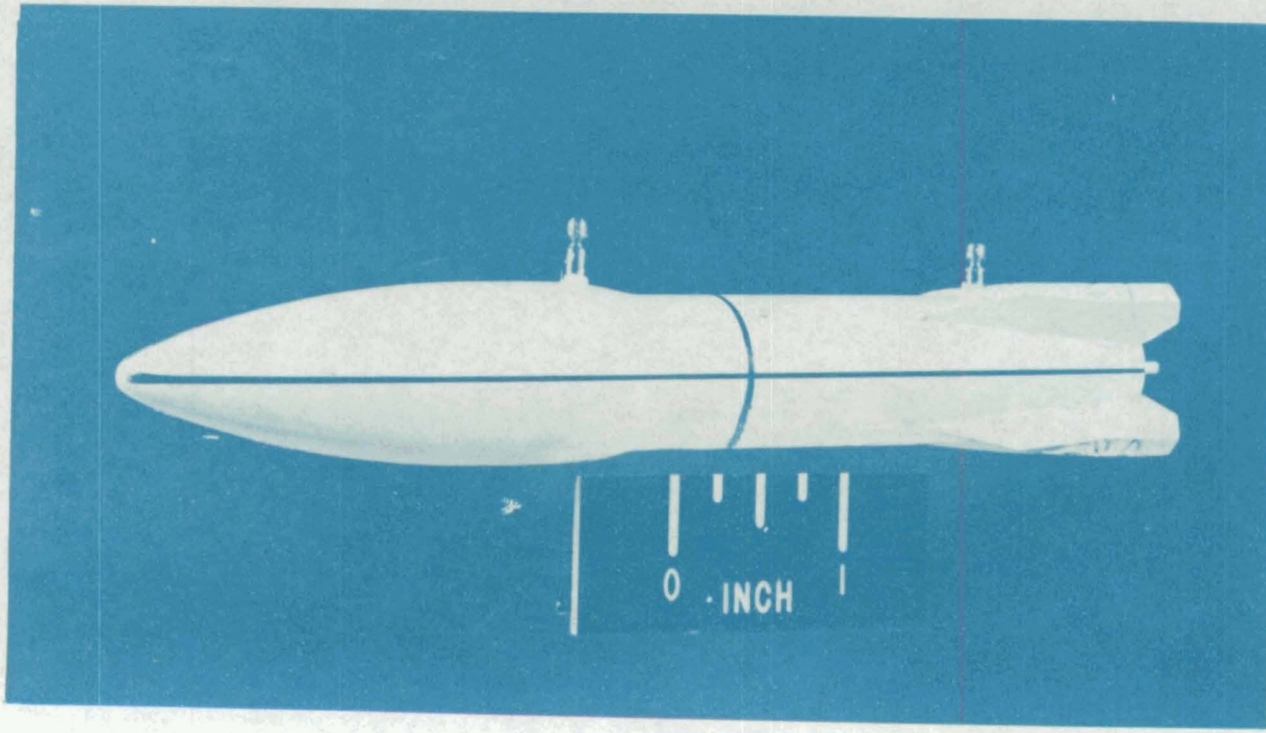
TABLE I.- MB-1 ROCKET MODEL ORDINATES

x, in.	r, in.
0.248	0.166
.497	.248
.744	.312
.991	.362
1.239	.398
1.497	.421
1.927	.429
2.212	.429
2.618	.372
4.139	.372
4.701	.359
5.495	.279

TABLE II.- TEST SEQUENCE AT $M = 1.59$ AND $\alpha_f = 2.0^\circ$ SIMULATING 18,670 FEET

Test	Figure	Number of Falcon missiles, N_f	$\dot{z}_o$, ft/sec	M_o, ft-lb	Δt, sec.
1	3	0	29.0	-2,000	0.00202
2	3	0	28.5	-1,100	.00205
3	4	2	28.5	-1,100	.00205
4	4	4	28.5	-1,100	.00205
5	4	4	28.5	-1,100	.00205
6	5	2	27.3	-2,000	.00203
7	5	4	27.3	-2,000	.00205
8	6	0	23.0	-1,170	.00205
9	6	2	23.0	-1,170	.00205
10	6	4	23.0	-1,170	.00203

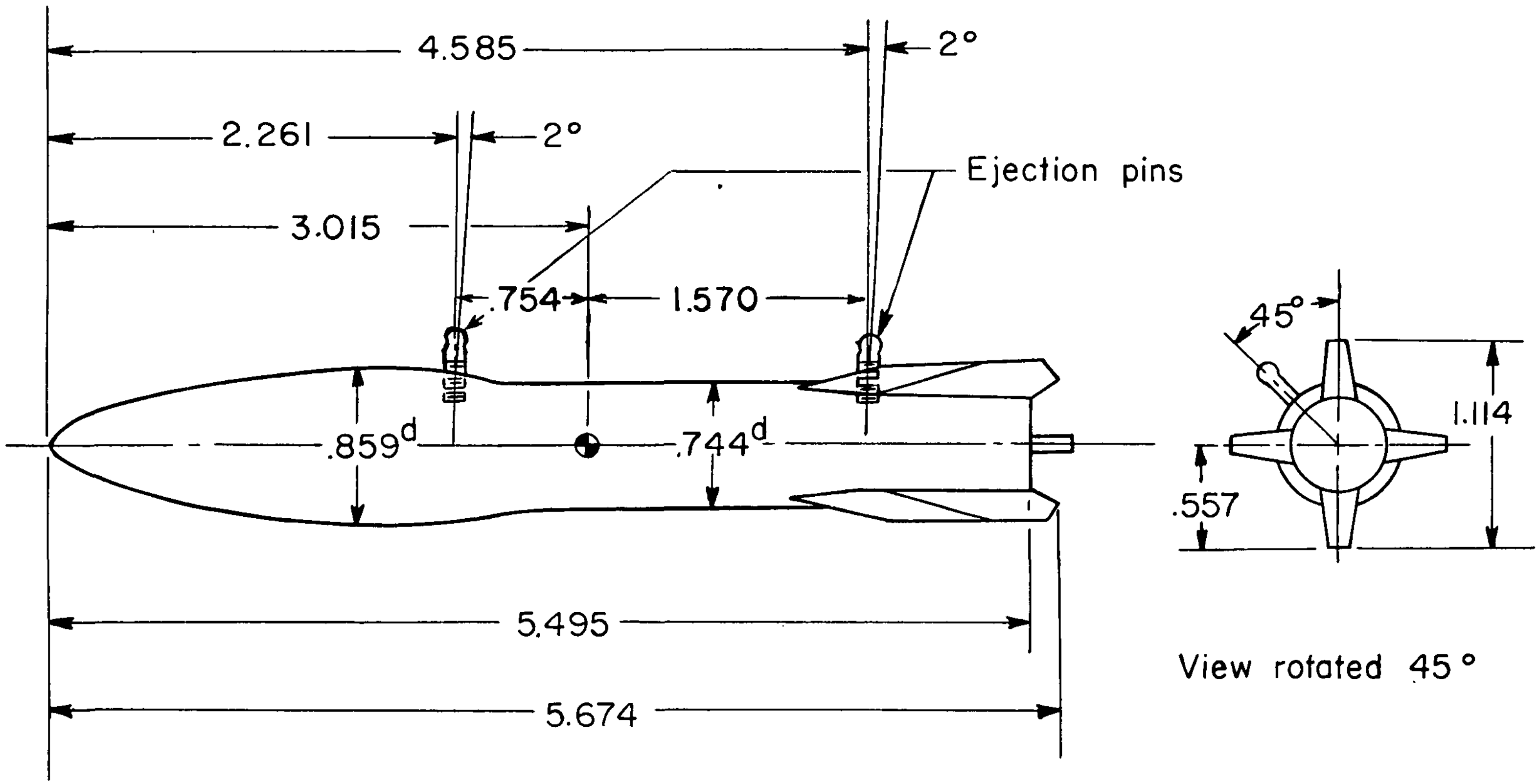
[redacted]



(a) Photograph of model. L-96601.1

Figure 1.- A 0.04956-scaled model of the MB-I rocket.

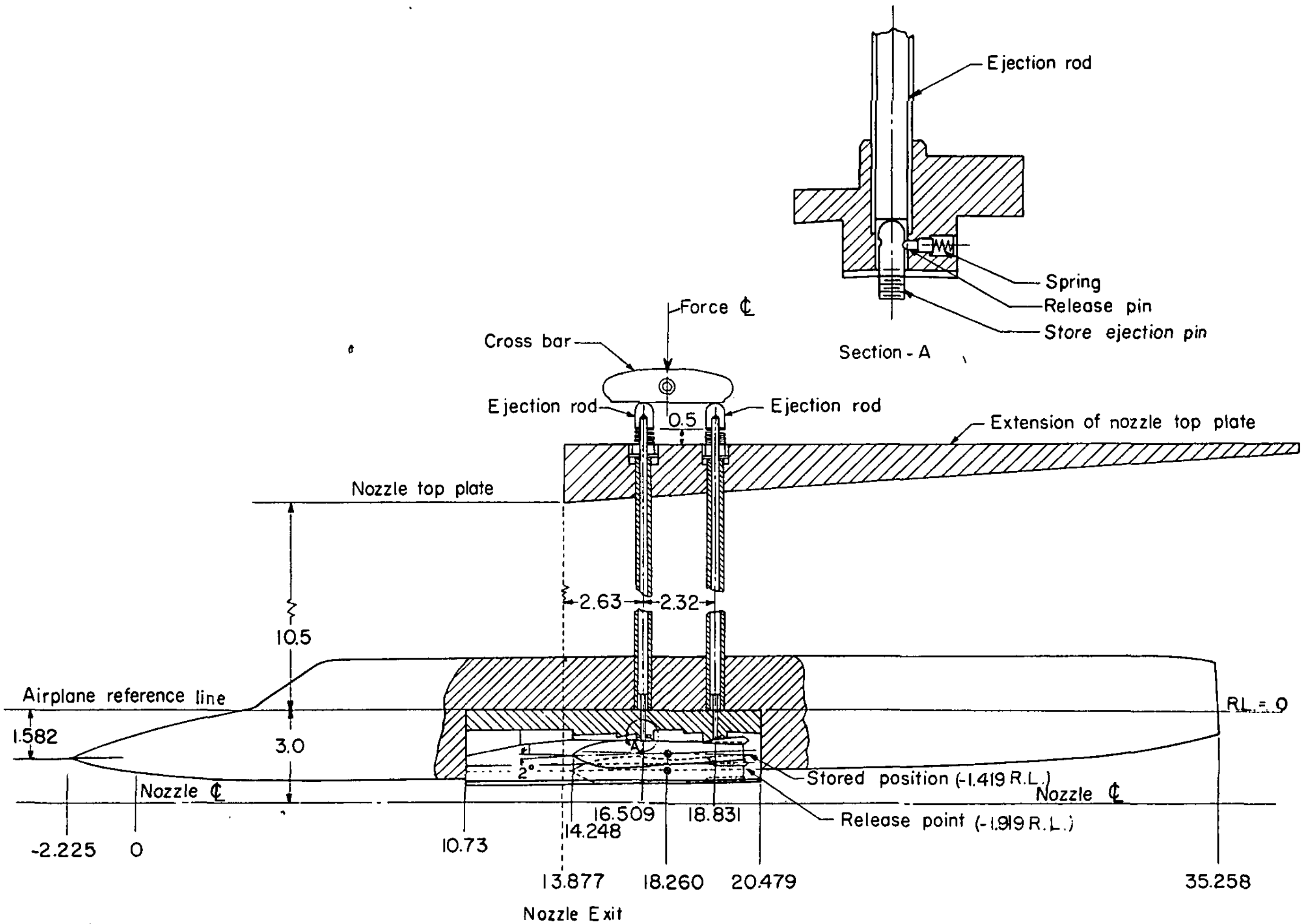
[redacted]



(b) Sketch of model. All dimensions are in inches.

Figure 1.- Concluded.

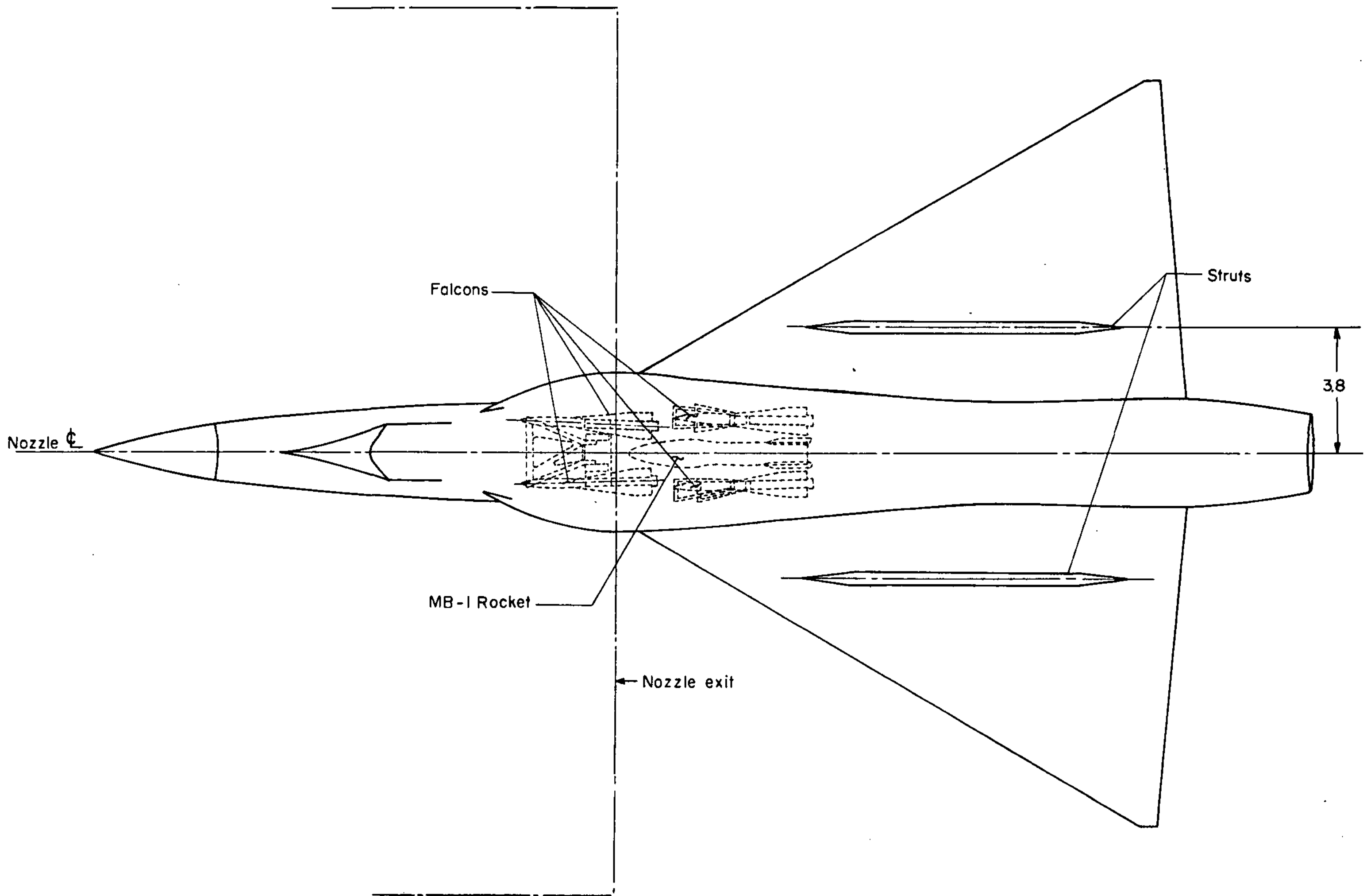
[redacted]



(a) Side view.

Figure 2.- The 0.04956-scaled model of the Convair F-106A airplane in preflight test facility. All dimensions are in inches.

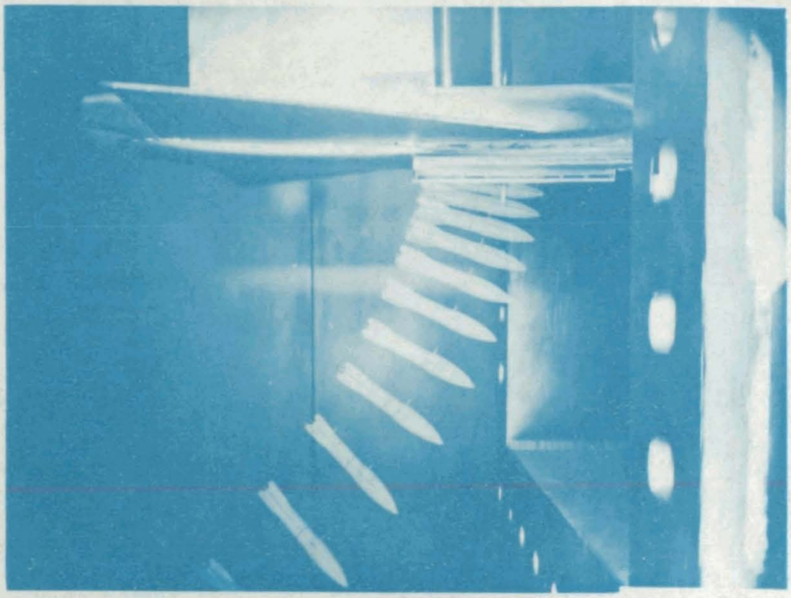
[redacted]



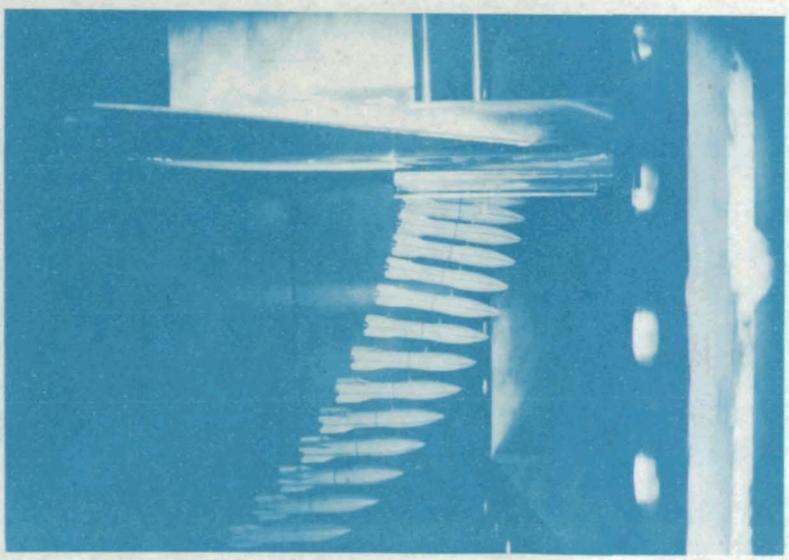
(b) Top view.

Figure 2.- Concluded.

[redacted]



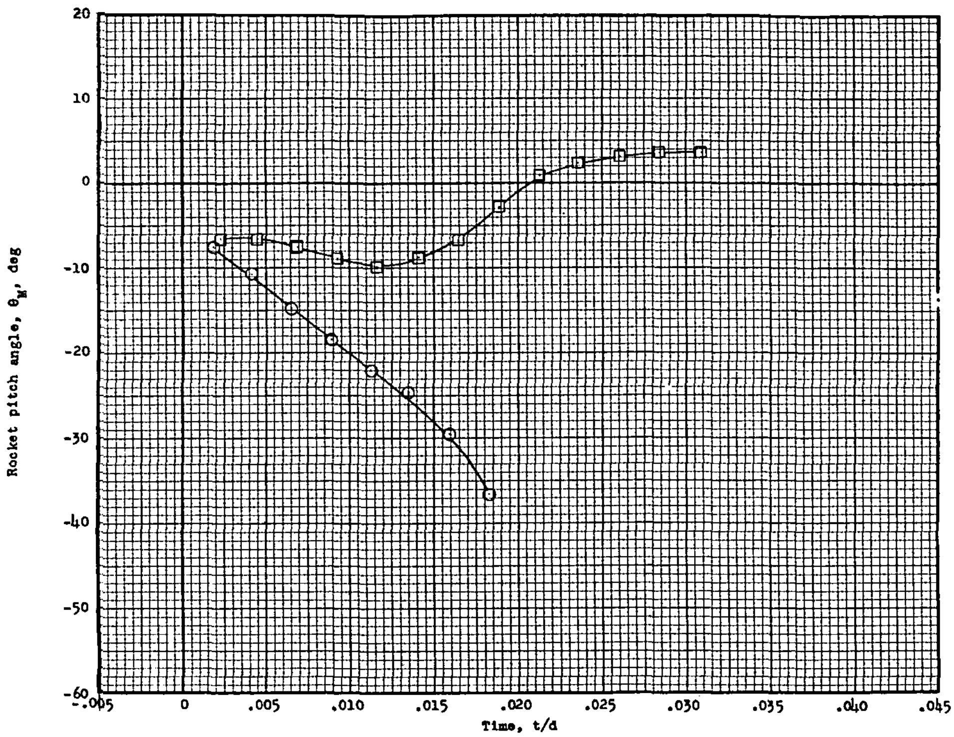
Test 1; M_o = -2,000 foot-pounds; $\dot{z}_o$ = 29.0 feet per second.



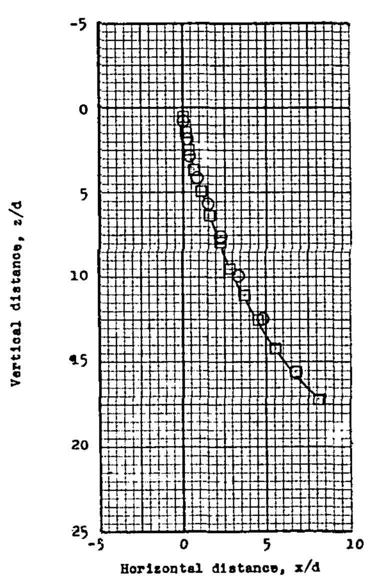
Test 2; M_o = -1,100 foot-pounds; $\dot{z}_o$ = 28.5 feet per second.

(a) Stroboscopic photographs. L-57-1584

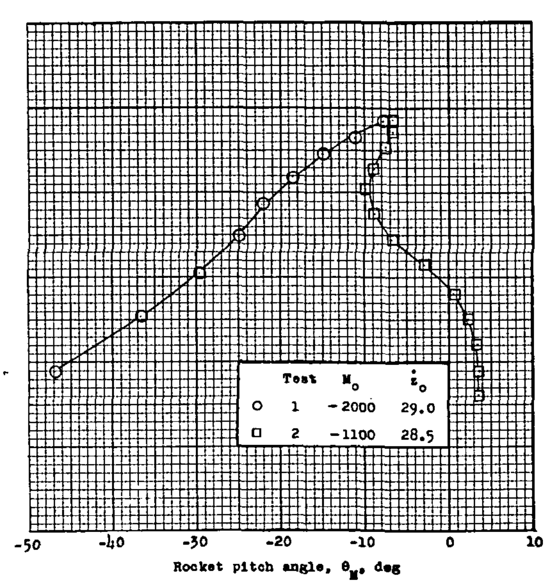
Figure 3.- MB-I rocket ejections with changes in initial pitching moment for $N_f = 0$.



(b) Oscillations.

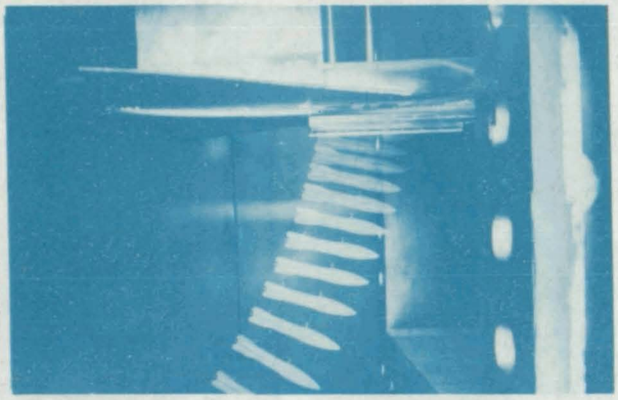


(c) Trajectories.

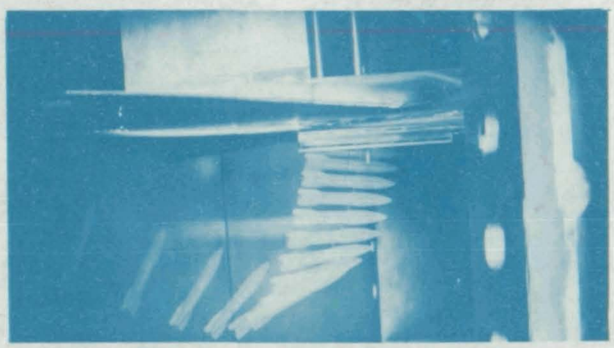


(d) Oscillations trajectories.

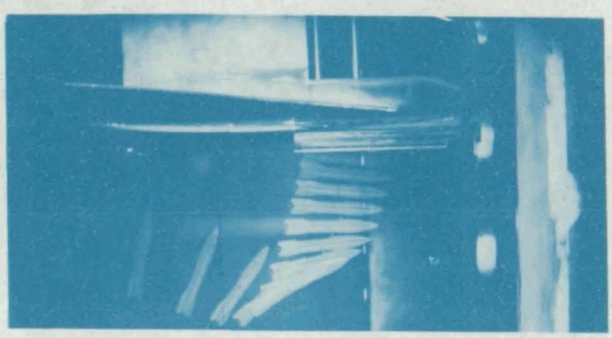
Figure 3.- Concluded.



Test 3; $N_f = 2$.



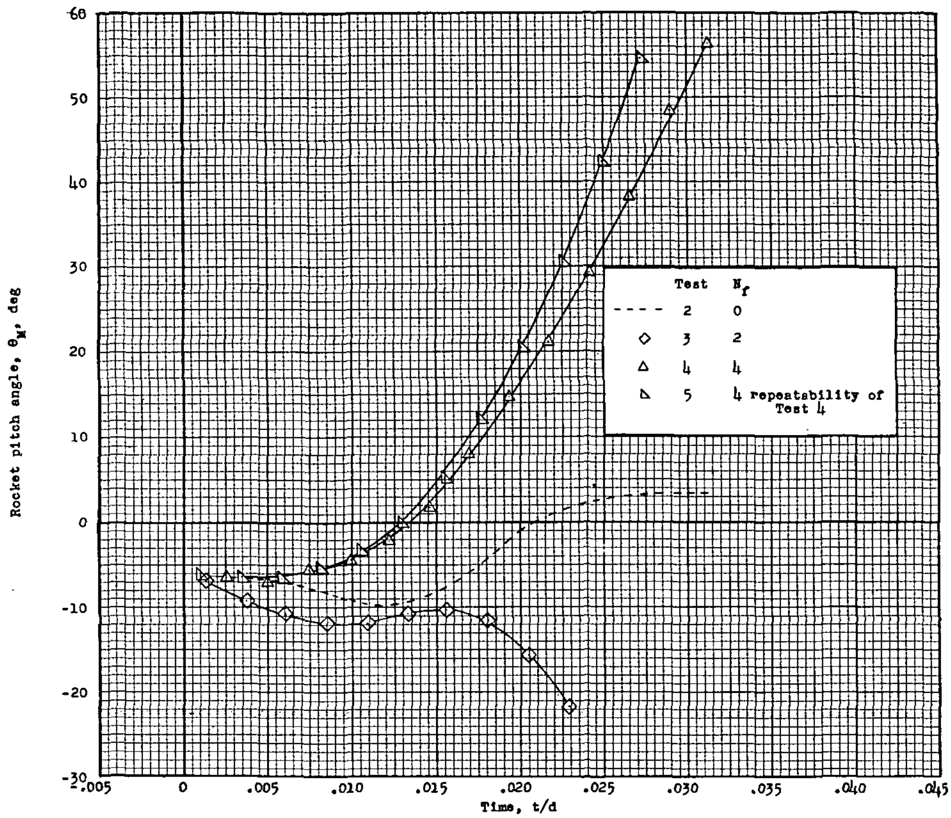
Test 4; $N_f = 4$.



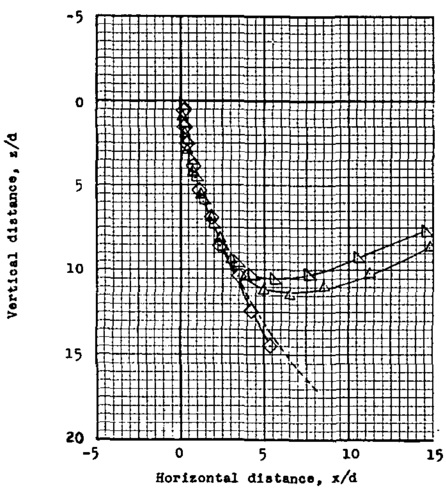
Test 5; $N_f = 4$; repeatability of test 4.

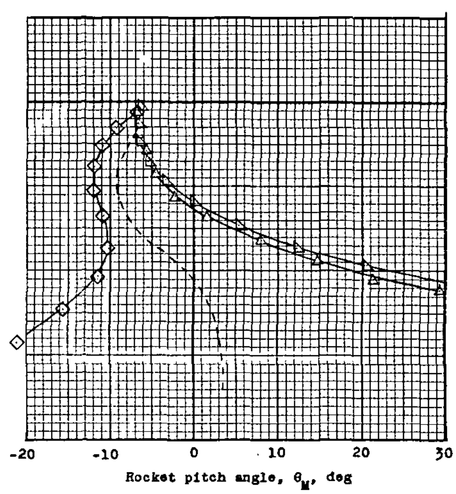
(a) Stroboscopic photographs. L-57-1585

Figure 4.- MB-I rocket ejections with changes in missile bay. $M_o = -1,100$ foot-pounds; $\dot{z}_o = 28.5$ feet per second.



(b) Oscillations.

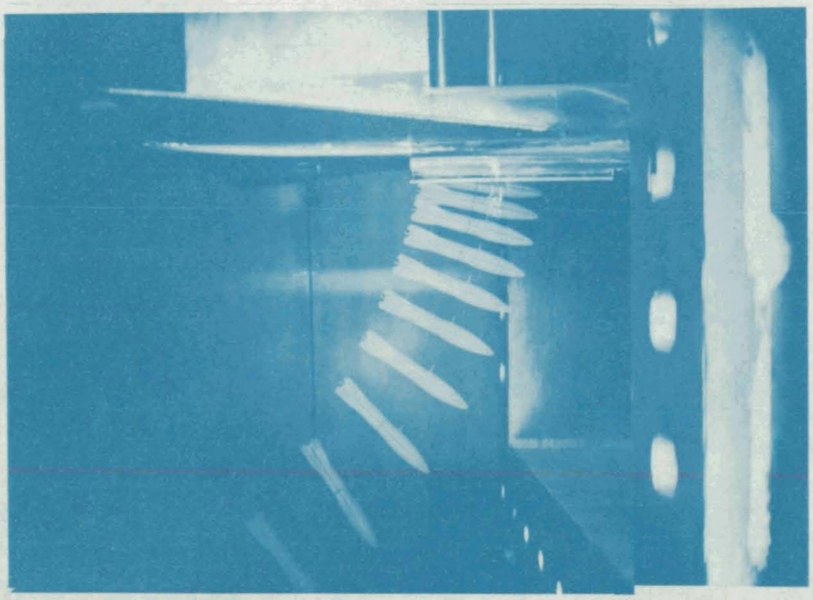




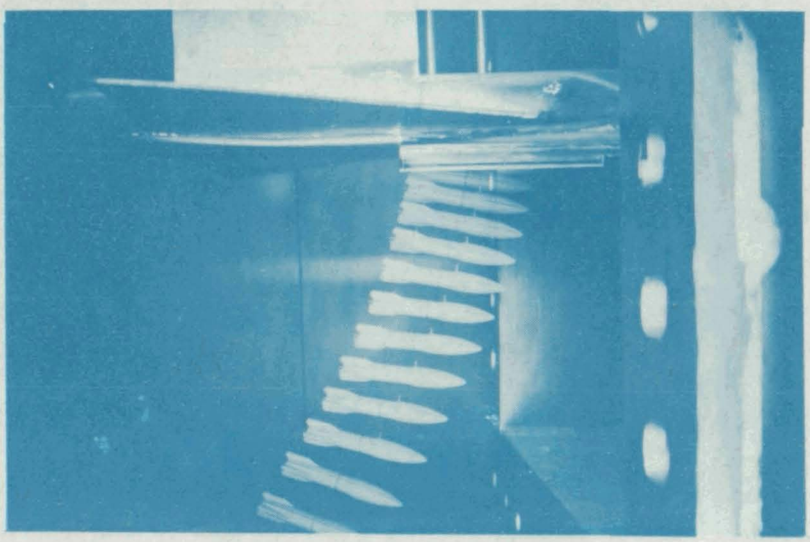
(c) Trajectories.

(d) Oscillations trajectories.

Figure 4.- Concluded.



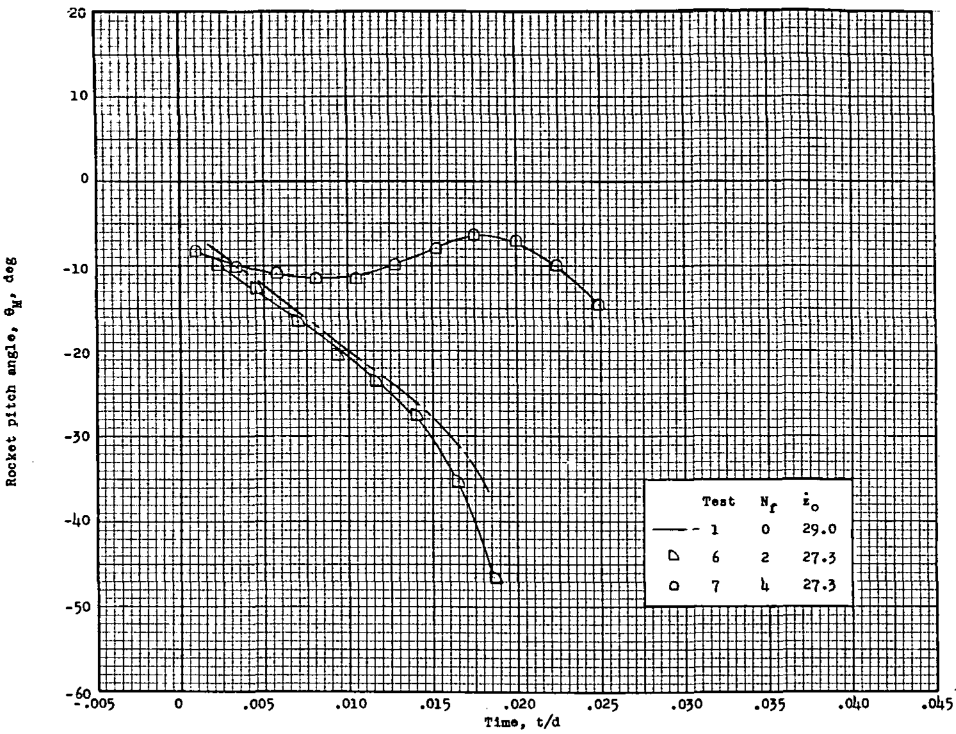
Test 6; $N_f = 2$; $\dot{z}_o = 27.3$ feet per second.



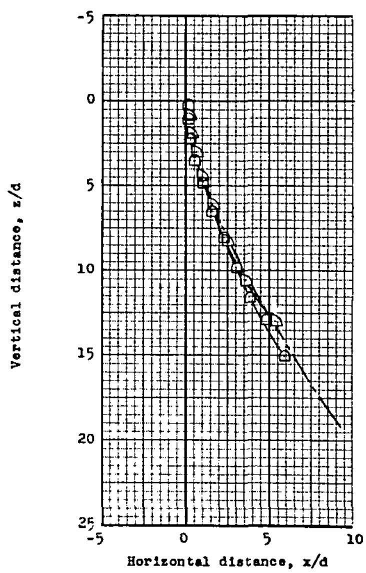
Test 7; $N_f = 4$; $\dot{z}_o = 27.3$ feet per second.

(a) Stroboscopic photographs. L-57-1586

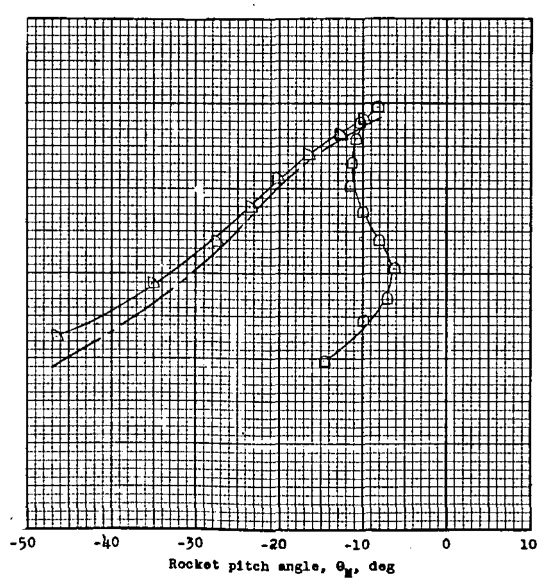
Figure 5.- MB-I rocket ejection with changes in missile bay. $M_o = -2,000$ foot-pounds.



(b) Oscillations.

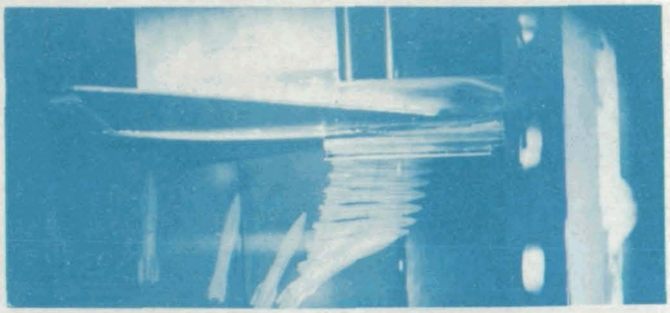


(c) Trajectories.

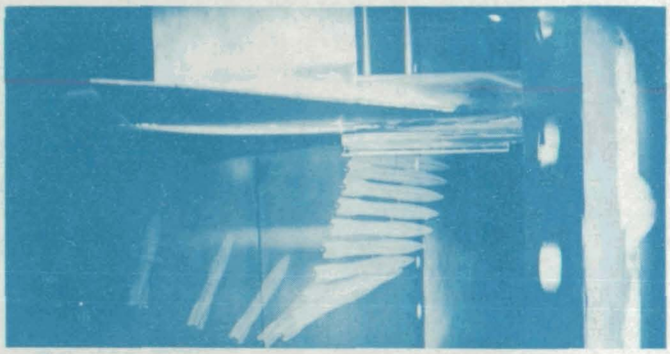


(d) Oscillations trajectories.

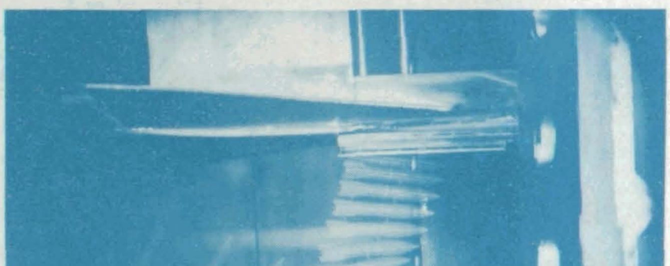
Figure 5.- Concluded.



Test 8; $N_f = 0$.



Test 9; $N_f = 2$.



Test 10; $N_f = 4$.

(a) Stroboscopic photographs. L-57-1587

Figure 6.- MB-I rocket ejections with changes in missile bay.
$\dot{z}_o = 23.0$ feet per second; $M_o = -1,170$ foot-pounds.

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COORD. NO. AF-AM-57

By John B. Lee

ABSTRACT

An investigation has been made of the release characteristics of the MB-1 rocket from a 0.04956-scaled model of the Convair F-106A airplane. Tests were conducted in the 27- by 27-inch preflight jet of the Langley Pilotless Aircraft Research Station at Wallops Island, Va., at a Mach number of 1.59 at an 18,670-foot simulated altitude. The purpose of the investigation was to determine the ejection velocities and pitching moments required to eject the MB-1 rocket at near level attitude with the fin tips retracted. Successful ejections were made by applying the proper combination of ejection velocity and nose-down pitching moment at release to counteract the nose-up moments produced by aerodynamic forces.

INDEX HEADINGS

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